Reduction of Grid Fault Synchronization Time for Distributed Generation Systems by Application of Hysteresis PWM Technique

Vijay Malviya[1], Prof. Santosh Kumar[2]

[1]Mtech. Scholar, [2]Research Guide

Millennium institute of technology and science, Bhopal

Abstract - An electric grid is an interconnected network for delivering electricity from suppliers to consumers. Electrical grids are affected by various occurrences like continuous connection and disconnection of loads, harmonies, faults caused by nature or equipment failure. Distributed power generation systems (DPGS). Should ride through grid disturbance without tripping as successfully as the conventional power plants they replace. The widespread use of power electronics systems will result even better performance than the conventional power plants. This requires the improvement of control and design of power converters for ride through different kinds of faults. The control scheme of the grid-side converter (GSC) mostly depends on two cascade loops. One is an internal current loop, which regulates the grid current and another one is external voltage loop, which controls the de-link voltage. The control of the GSC is based on a de-link voltage loop and it is designed for balancing the power flow in the system. Solutions based on the installation of STATCOMs and dynamic voltage regulators (DVRs), as well as on advanced control functionalities for the existing power converters of distributed generation plants, have contributed to enhance their response under faulty and distorted scenarios and, hence, to fulfill these requirements. The decoupled double synchronous reference frame phase-locked loop (PLL), the dual second order generalized integrator PLL, and the three-phase enhanced PLL, designed to work under such conditions.

Keywords- Electric variable measurements, electrical engineering, frequency estimation, frequency-locked loops, harmonic analysis, monitoring, synchronization.

I. INTRODUCTION

The Environmental friendly renewable energy technologies such as wind and solar energy systems are among the fleet of new generating technologies driving the demand for distributed generation of electricity. Power Electronics has initiated the next technological revolution and enables the connection of distributed generation (DG) systems to the grid. Thus the increasing power demand will be met by Distributed Generation (DG) system which are based on renewable energy sources such as solar power, wind power, small hydro power etc. These systems need to be controlled properly in order to ensure sinusoidal current injection into grid. However, they have a poor controllability due to their intermittent characteristics. Grid connected inverter plays a vital role in maintaining voltage at the point of common coupling (PCC) constant. For the reliable operation of utility grid based on DG system, the power plant operators should satisfy the grid code requirements such as fault ride through, grid stability, grid synchronization and power control etc. The major issue associated with DG system is their synchronization with utility voltage vector. The information about the phase angle of utility voltage is tracked accurately to control the flow of active and reactive power and to turn on and off power devices.

Due to the issue of the carbon credits and environmental pollution, research into renewable power generation systems and the commercialization of this technology are actively underway worldwide. In particular, wind power has shown a rapid growth among the various renewable energy resources.

In some European countries such as Denmark, UK, and Germany, wind power generation systems account for a large portion of the total amount of generated power. To smooth the effects of high wind power penetration on power system stability and power quality, the transmission system operators (TSOs) in many countries have established special grid codes for wind power integration into the grid. The grid codes for wind power systems include technical requirements for the integration of wind power systems to power grids such as active and reactive power control, voltage and frequency limits and behavior during grid faults.

A. Grid voltage monitoring

To guarantee the correct generation of the reference signals and to meet the demands regarding the operation boundaries with respect to voltage amplitude and frequency values required by standards, the grid-connected converters need an accurate and fast detection of the phase angle, amplitude and frequency of the utility voltage. The grid voltage monitoring can be easily influenced by the grid disturbances, thus providing inaccurate values to the control. This can lead to poor performances or undesired disconnections of the DPGS.

B. Grid impedance estimation

The grid impedance value can be used by the control of numerous grid-connected systems. Some of the applications which rely on the grid impedance value can be enumerated as follows: current controllers with improved stability and dynamic performance; active filter control; detection of grid faults and grid unbalances; compliance with certain stringent standards for islanding detection; non-linear current controllers including hysteresis and predictive control

II. GRID VOLTAGE SYNCHRONIZATION

Converter interfaced DG units must be synchronized with the utility system. Grid synchronization is a challenging task especially when the utility signal is polluted with disturbances and harmonics or is of a distorted frequency. A phase detecting technique provides a reference phase signal synchronized with the grid voltage that is required to control and meet the power quality standards. This is critical in converter interfaced DG units where the synchronization scheme should provide a high degree of insensitivity to power system disturbances, unbalances, harmonics ,voltage sags, and other types of pollutions that exist in the grid signal. In general, a good synchronization scheme must i) proficiently detect the phase angle of the utility signal, ii) Track the phase and frequency variations smoothly, and iii) forcefully reject disturbances and harmonics. These factors, together with the implementation simplicity and the cost are all important when examining the credibility of a synchronization scheme. There are two popular grid synchronizing techniques listed below.

A. Zero Crossing Detectors (ZCD):

Zero-crossing detector is an applied form of a comparator. Either of the op-amp based circuits discussed can be employed as zero-crossing detector. In some applications the input signal may be low frequency one (i.e. input may be a slowly changing waveform). In such a case output voltage may not switch quickly from one saturation state to another. Because of the noise at the input terminals of op-amp, there may be fluctuation in output voltage between two saturation states (+ Vsat and - Vsat voltages). Thus zero crossing may be detected for noise voltages as well as input signal. Both problems can be overcome if we use regenerative or positive feeding causing the output voltage to change faster and eliminating the false output transitions that may be caused due to noise at the input of the op-amp. Thus we prefer PLL based methods for the detection of Phase angle when compared to Zero Crossing Detector.

B. Phase Locked Loop (PLL):

A phase-locked loop is a control system that generates an output signal whose phase is related to the phase of an input "reference" signal [5].This circuit compares the phase of the input signal with the phase of the signal derived from its output oscillator and adjusts the frequency of its oscillator to keep the phases matched. The output signal from the phase detector is used to control the oscillator in a feedback loop. Frequency is the time derivative of phase. Keeping both the input and output phase in lock step implies keeping the input and output frequencies in lock step. Consequently it can track an input frequency or it can generate a frequency that is a multiple of the input frequency. Figure 2.1 Demonstrated bolock diagram of a conventional PLL framework.

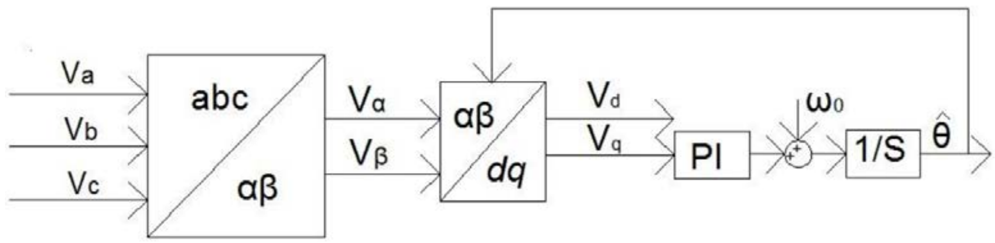

Figure: 2.1. Basic Block Diagram of the Conventional PLL.

III. RELATED WORK

A. Luna et al.[1] The actual grid code requirements for the grid connection of distributed generation systems, mainly wind and photovoltaic (PV) systems, are becoming very demanding. The transmission system operators (TSOs) are especially concerned about the low-voltage-ride-through requirements. Solutions based on the installation of STATCOMs and dynamic voltage regulators (DVRs), as well as on advanced control functionalities for the existing power converters of distributed generation plants, have contributed to enhance their response under faulty and distorted scenarios and, hence, to fulfill these requirements. In order to achieve satisfactory results with such systems, it is necessary to count on accurate and fast grid voltage synchronization algorithms, which are able to work under unbalanced and distorted conditions. This Research analyzes the synchronization capability of three advanced synchronization systems: the decoupled double synchronous reference frame phase-locked loop (PLL), the dual second order generalized integrator PLL, and the three-phase enhanced PLL, designed to work under such conditions. Although other systems based on frequency-locked loops have also been developed, PLLs have been chosen due to their link with dq0 controllers. In the following, the different algorithms will be presented and discretized, and their performance will be tested in an experimental setup controlled in order to evaluate their accuracy and implementation features.

Y. Li, J. Li, Y. Lei and W. Sun,[2] Grid synchronization is one of the key issues for distributed power generation system. In recent years, an increasing number of new energy generation systems are connected to the grid. This greatly affects stability of the grid, which brings difficults for inverters to be connecterd to the grid. So accurate detection of voltage frequency, positive and negative sequence components under complex and unbalanced grid faults becomes one of the key issues of control of grid-connected inverters. In these research three grid synchronization methods are introduced and simulation was done to see their performance under complex and unbalanced grid condition. Simulation results showed their availability. Advantages and disadvantages of them are compared in order to be applied to different situations.

S. N. Muneshwar, R. P. Hasabet, P. Kose and A. A. Bhole,[3] Protection is one of the important key features when it comes to power system. The objective of protection scheme is to keep the power system stable by isolating only the components that comes under the fault. The modernized power grids are complex and hence need to be monitored, control and protected by wide area measurement system (WAMS). WAMS helps to fetch, time synchronized data of power system operating states. This feature of WAMS will make it very popular in the coming generation smart grid protection and control. The purpose is to increase the overall efficiency and reliability of power system for all power stages via significant dependence on WAMS as distributed intelligence agents with improved monitoring, protection and control capabilities of power network. One of the finest techniques for WAMS is Phasor measurement unit (PMU). This research speculates detection of fault location and protection of power system using PMU. The principle of the protection scheme depends on comparing positive sequence voltage magnitudes at each bus during fault conditions inside a system protection center to detect the nearest bus to the fault. Then the absolute differences of positive sequence current angles are compared for all lines connecting to this bus to detect the faulted line. The conventional methods that are been used for protection are not as accurate as the PMU because PMU uses GPS system for time synchronized data. This exploration features simulation of interconnected network system for 220 KV line using MATLAB Simulink.

T. A. Youssef, M. Amin and O. A. Mohammed, [4] in grid-connected wind energy conversion systems (WECSs), phase locked loop (PLL) technique became widely used to enhance the stability and power quality. However, the accuracy of PLL is one of the major aspects that influence the system performance. Conventional synchronous-reference frame PLL (SRF-PLL) techniques have difficulty of low accuracy, frequency fluctuation, power oscillation and poor power quality. To improve these drawbacks, this research proposes a new improved PLL technique. A comparative study for the conventional techniques and the developed technique is introduced. Two types of current controllers (hysteresis and vector oriented control) are compared. A reconfigurable inverter controller is also proposed here as an effective method that supports both grid-connected and stand-alone operation modes. This provides stable operation under various grid conditions and maintains stable frequency reference during islanding mode. More advantages include voltage unbalance operation capability and robustness under fault conditions. Simulation results are carried out to validate the proposed solution. The results have demonstrated that the proposed technique is more efficient than other conventional techniques to achieve better performance, improved power quality, and enhanced stability under various conditions.

M. Ashabani and Y. A. R. I. Mohamed,[5] This research presents a new control topology to enable effective integration of voltage source converters (VSCs) in weak grids. The controller has two main parts. The first part is a linear power-damping and synchronizing controller which automatically synchronizes a VSC to a grid by providing damping and synchronizing power components, and enables effective full power injection even under very weak grid conditions. The controller adopts cascaded angle, frequency and power loops for frequency and angle regulation. The controller emulates the dynamic performance of synchronous machines, which eases grid integration and provides a virtual inertia control framework for VSCs to damp power and frequency oscillations. Although the linear controller offers stable and smooth operation in many cases, it cannot ensure system stability in weak grids, where sudden large disturbances rapidly drift system dynamics to the nonlinear region. To overcome this difficulty, a supplementary nonlinear controller is developed to assist the linear controller and enhance system performance under large-signal nonlinear disturbances, such as self-synchronization, disturbances in grid frequency and angle, high power injection in very weak grids and fault-ride-through conditions.

A. Boussaid, Y. Maouche, A. L. Nemmour and A. Khezzar,[6] This research proposes a modified PQ theory for detecting the positive and negative components of the utility voltages under faulty grid conditions. Fast and exact detecting of those sequences is important to achieve the operating at unity power factor integration of distributed generations into the main grid and for other uses. A detailed description of the proposed method has been accomplished. A phase lockedloop on synchronous rotating frame (SRF PLL) is commonly used to detect the exact phase angle; nevertheless this solution failed immediately to extract the two sequences under unbalanced and distorted conditions. The FMV filter constitutes a very interesting alternative to obtain the phase angle precisely and instantaneously; in this way, different kind of filters with a narrow bandwidth have been used for the separation of positive and negative components; however the response time is extended and an important phase delay is generated. the calculation of the mean value of the instantaneous power is a way to eliminate the AC component with a time response less than one of half of period. The obtained simulation results have been confirmed experimentally using a Dspace 1104 platform.

D. Sharma, B. Sen and B. C. Babu,[7] Distributed Generation (DG) System is a small scale electric power generation at or near the user's facility as opposed to the normal mode of centralized power generation. In order to ensure safe and reliable operation of power system based on DS, grid synchronization algorithm plays a very important role. This research presents a Double Synchronous Reference Frame (DSRF) phase locked loop (PLL) based on synthesis circuit for grid synchronization of distributed generation (DG) system under grid disturbances. Due to flexible in characteristics, DSRF PLL can accurately detect the phase irrespective of the grid conditions. Further, it demonstrates how the PLLs track the phase angle during some of the major abnormal grid conditions like voltage unbalance, line to ground fault and voltage sag etc. The superiority of DSRF PLL over SRF PLL is well illustrated by the simulations results obtained from MATLAB/SIMULINK environment.

IV. PROBLEM STATEMENT

Due to the increased number of DPGS connected to utility grid, instability of the DG systems and of the grid itself are subjected to instability problems. One of the important issues of the DPGS connected to the utility network is the synchronization with the grid voltage vector [8]. In grid-connected wind energy conversion systems (WECSs), phase locked loop (PLL) technique became widely used to enhance the stability and power quality. However, the accuracy of PLL is one of the major aspects that influence the system performance. Conventional synchronous-reference frame PLL (SRF-PLL) techniques have difficulty of low accuracy, frequency fluctuation, power oscillation and poor power quality [4].

The detection of the positive sequence voltage component at fundamental frequency is required for the control of distributed generation. The magnitude and phase angle of the positive sequence voltage is used for the synchronization of the converter output variables or for the transformation of the state variables into rotating reference. Regardless of the technique used in the system detection i.e. using a Zero Crossing Detector (ZCD) or a Phase Locked Loop (PLL), the amplitude and the phase angle of the positive sequence component must be fast and accurately obtained, even if the utility voltage is distorted or unbalanced[9]

V. CONCLUSION

PLL can perfectly detect the positive- and negative-sequence component of the voltage bv cancelling out the oscillation in the ease voltage unbalanced condition, PLL cannot perfectly detect the positive- and negative voltage and frequency of the unbalanced voltage, when there is harmonic distortion in the input voltage. This is because PLL only cancels out the 2u oscillation with the help of decoupling network. Meanwhile, it cannot cancel out the oscillation higher than 2u. Which means if the amplitude of the harmonies is higher enough; it can cause much problem in the detection of positive- and negative sequence component of the voltage. Conventionally, the fundamental component method has been used to measure the fundamental voltage and also to detect fault conditions in power systems. However, this method takes more than one cycle to accurately measure the voltage magnitude after a fault occurs. In addition, the detection performance of the conventional method can be degraded when the system frequency fluctuates.

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